

9. Upper tree limit and land use on the upper slopes of Ferrah Amba, the peak of Tigray (3939 m a.s.l.)

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1. Research question

The links between decreasing size and volume of the glaciers in East Africa's tropical mountains and the position of climatic belts on the one hand and global warming on the other have led to various interpretations on the occurrence of global warming and its magnitude and impacts in this part of the world. Here, we investigate the existence of temperature changes, its interaction with anthropogenic and zoogenic activity and their impacts in high mountain regions by analyzing the position of the upper *Erica* limit in northern Ethiopia and compare it to nearby massifs (Fig.1).

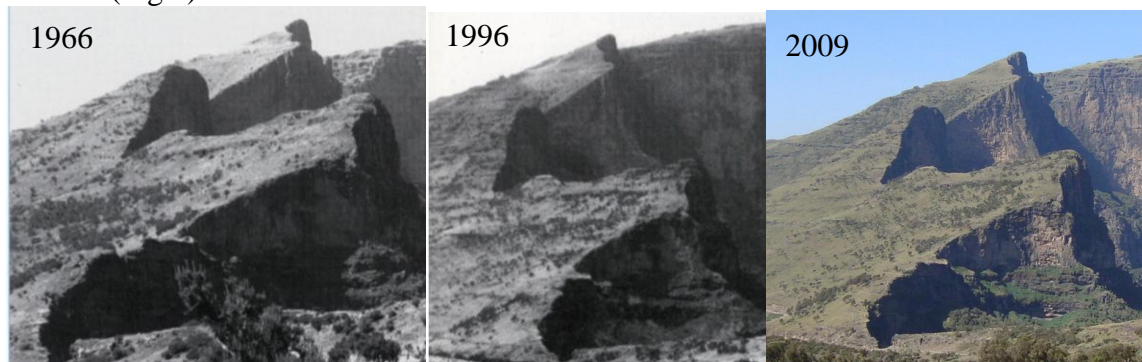


Fig. 1. Upward movement of the upper *Erica* limit in Simien mountains National Park, between 1966, 1996 (Nievergelt, 1998) and 2009 (own observations), at elevations of 3790, 3840 and 3900 m a.s.l. Such upward movement could not be observed on Ferrah Amba.

Beyond the Ayba valley there is another transverse range-that of Ferrah, also named after a mountain mass rising up on the right of the road. This Amba-Ferrah is a succession of grand precipices - a glorious mass of rock, not terminating in a peak like Alaji, but in angular walls of rock, with bright green steeps and ledges intersecting them. It rises up immediately on the right of the pass, which winds up the shelving hills down which a bright stream flows into the Ayba valley. The hills are covered with juniper bushes, and the hollows are golden with a pretty St.-John's-wort, which here first makes its appearance. On this pass, too, the kosoo tree was first seen. Large boulders covered with moss are scattered over the grass, and here and there thickets of wild roses scent the air, growing with a bright purple indigo and a crotalaria. The gigantic thistle rises above all, and on the higher slopes there is a heath with a white flower.

Notes (JN): St.-John's-Wort = *Hypericum*; Kosso = *Hagenia*

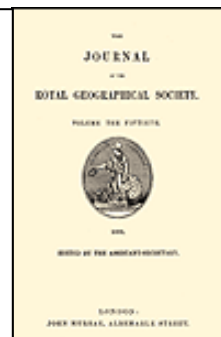


Fig. 2. First description of Ferrah Amba and its vegetation (Markham, 1868)

2. Study area

Ferrah Amba (“Mountain of Fears”) (12°52’N, 39°30’E, 3939 m a.s.l.) is the highest peak of Tigray; its first geographical description was made during the British military expedition to Ethiopia in 1868 (Fig. 2, Fig. 3).

3. Upper *Erica* limit and physiognomic treeline

Following concepts of (Holtmeier, 2009; Van Bogaert, 2010) we defined “Upper Erica limit” and “Physiognomic treeline”.



Fig. 3. Ferrah Amba in 1942. Photo D. Buxton (Meire et al., 2011).

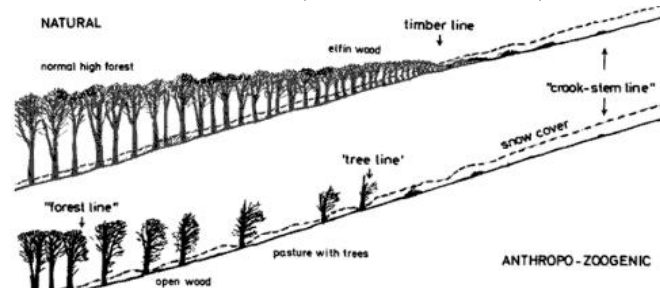


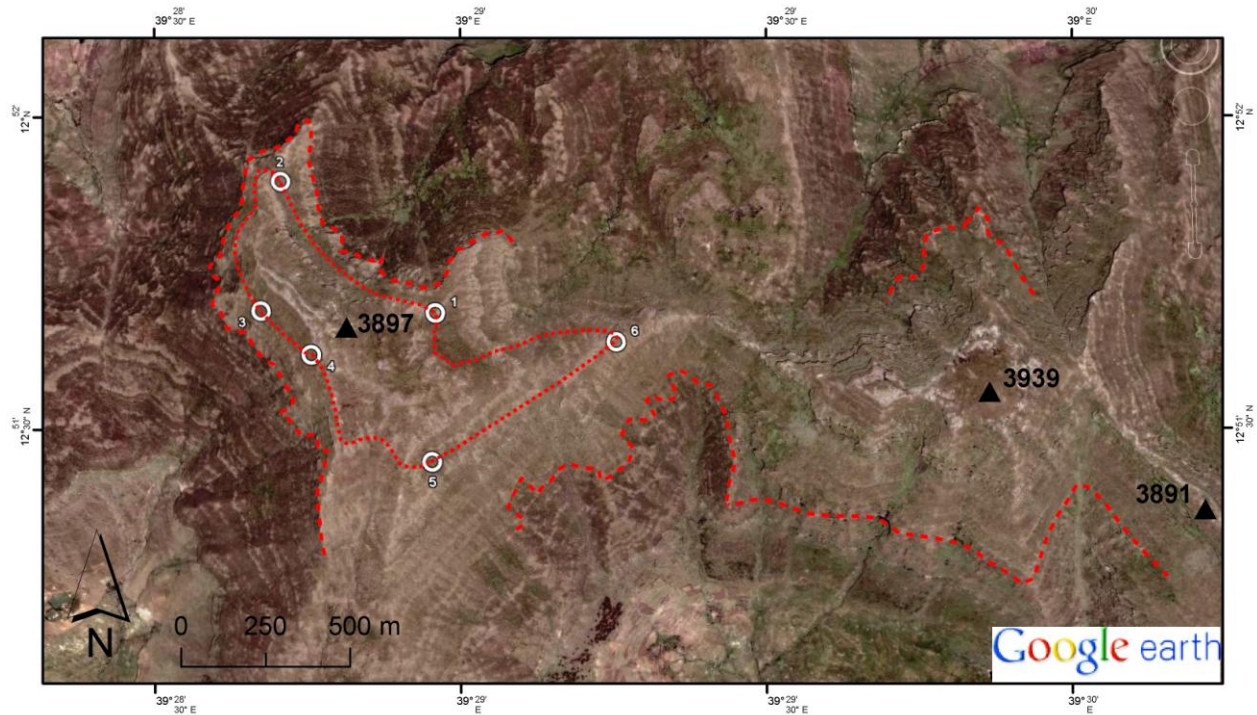
Fig. 4. Difference between natural and anthropo-zoogenic treeline in European mountains (after Ellenberg, 2009).



Fig. 5. *Erica arborea* grows from 3560 to 3840 m.a.s.l. The maximum height observed was 4 m and diameter 5 cm. Arrow indicates approximate location of excursion stop, at the foot of the hill in the middle plan.



Fig. 6. Some of the uppermost, isolated *Erica* specimen (upper Erica limit) at 3826 m a.s.l. Trees are not young, as witnessed by 1-2 cm thick stems. Neither here, nor in the forest downslope, regrowth could be observed. Note the clearly marked physiognomic treeline, at 3720 m.



- ▲ Peaks with elevation
- Upper Erica limit
- - - - Physiognomic treeline

Fig. 7. Based on field observations (February 2010), interpretation of Google Earth image, and of aerial photographs (1994). 1-6 are highest *Erica* specimen observed (3829-3862 m a.s.l.). For these upper limits, no changes could be found between the situations in 1994 and 2010.

4. Changes in cropping system



Fig. 8. Google Earth image of part of the northern slope of Ferrah Amba with terraces evidencing cultivation at 3450-3500 m a.s.l. Locally some cultivation takes place. Though this resembled at first to abandonment of agriculture, it is simply part of the cropping system in which land is only cultivated once in two years.



Fig. 9. In 2009, for the first time, wheat has been cultivated by a few farmers around Dogu'a village (here at 3380 m a.s.l.) assuming that with warmer climate it could grow – and it did! Neighbouring farmers were making plans to grow wheat at these elevations as of June 2010.

5. Changes in climate

Mekelle airport (2257 m): average monthly temperature

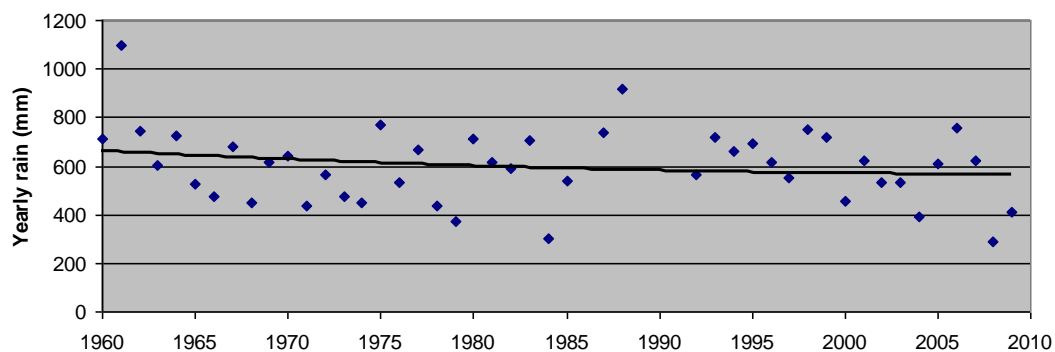
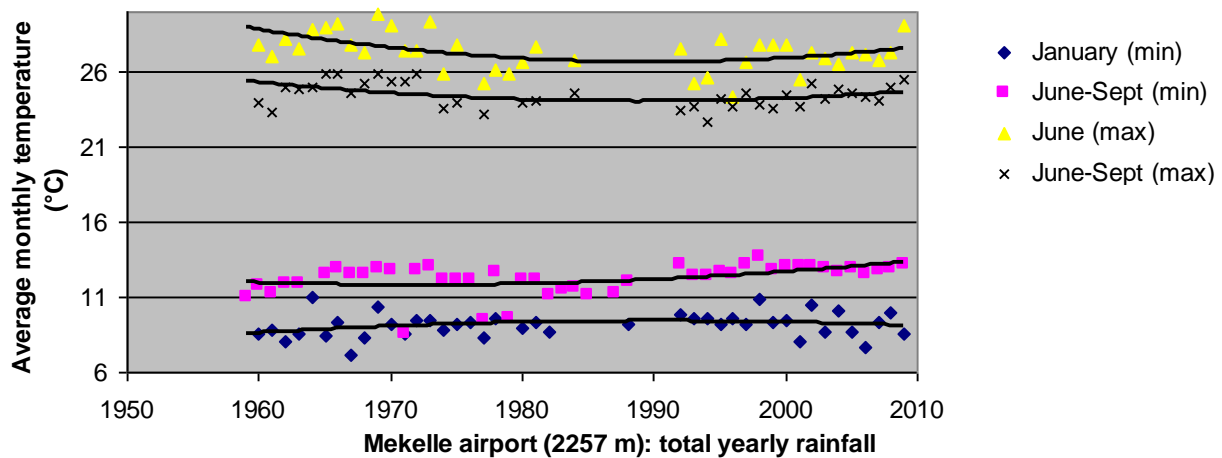
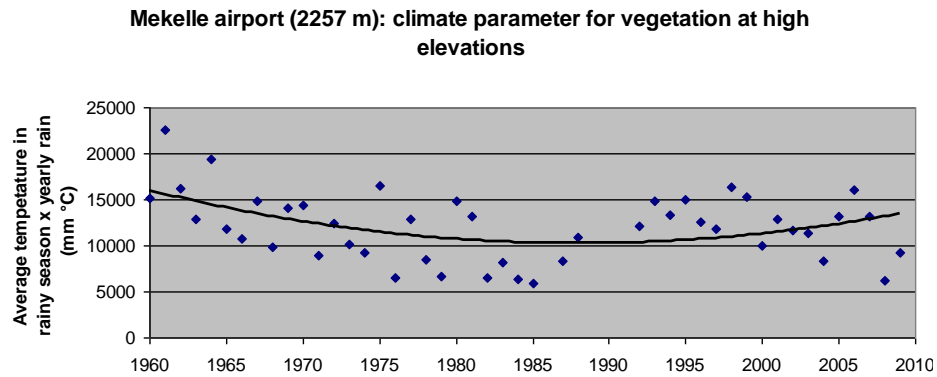


Fig. 10. Climate tendencies for Mekelle Airport (2257 m a.s.l. – data from NMSA), 80 km to the North. More nearby stations have only short time series, and all stations are located at least 1500 m lower than the peaks. Main tendencies are slight decrease in rainfall, as well as rising temperatures since the mid 1980s.



*Fig. 11. Climate parameter (average minimum temperature in the rainy season * total yearly rain), showing improved conditions for vegetation growth since the mid-1980s.*

6. Effects of deforestation on downstream areas



Fig. 12. The uppermost Juniperus procera at 3500 m. a.s.l., in an inaccessible place, evidences the previous existence of a forest, as also confirmed by local farmers.



Figure 13. Uprooting of Erica stumps destroys regeneration from the tree roots (inset)



Fig. 14. Hundreds of sheep are brought daily to the slopes of the mountain, here at 3700 m a.s.l. Livestock browsing impedes regeneration of Erica and other trees of the sub-alpine biome.

Besides the negative effects of deforestation on biodiversity and ecology, the inhabitants spontaneously pointed to us that the removal of the vegetation (hence decreased infiltration) has led to a strong decrease of the discharge of downstream springs (Fig. 15), which in its turn led to a decrease of the irrigated area. This is the reverse of what happens on Mt. Bela (near Sokota) where strong vegetation regrowth took place (due to protection of the mountain) and large irrigation areas were developed using the strongly developed discharges of the downslope springs (Nyssen et al., 2009a).



Fig. 15. The lower part of Dogu'a village (at around 3000 m a.s.l.). View on Monkocies Abdera church forest dominated by Juniperus procera. The surroundings of the hamlet are irrigated. Spring discharges (and hence the irrigated area) are however decreasing due to continuous deforestation in the upslope areas.

7. Discussion and conclusions

Climate change is evidenced by introduction of wheat at high elevations.

At high elevations, anthropogenic-zoogenic impact (grazing, woodcutting, earlier use of fire) seems to override effects of (warming) climate on upper species limit and physiognomic treeline.

In areas that have become recently protected (such as national park establishment in Simien), trees that have started growing more upward may also be ascribed to the protected status, and to regulations that prevent farmers from expanding farmlands upwards, even if climatic and topographic conditions would allow to do so.

Implications for land management: indiscriminate harvesting of wood for fire and other domestic purposes, and absence of seedling establishment and destruction of coppiced *Erica* by browsing, will easily result in the further degradation of the last sub-alpine forest of Tigray, as well as the afro-alpine vegetation.

Unlike nearby mountain areas, the territory of the villages established on the flanks of Ferrah Amba extend from the top of the mountain to its foot. Downslope resettlement seems possible, as conflicts between villages may be largely avoided. Spontaneously, some villagers have already moved downslope to use the irrigation water (Figure 15). The overall vision for natural resource and agricultural development of this area be

- (1) to protect the afro-alpine and sub-alpine vegetation: protection of biodiversity and enhanced infiltration
- (2) subsequent development of springs in the downstream area enhances the downslope movement of inhabitants
- (3) development of community-based tourism will generate additional income. The big opportunity is that this area is easily accessible from the main road; a weakness should however be overcome that is to first allow the regeneration of the afro-alpine and subalpine vegetation and wildlife.

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